A survey of the level of horse owner uptake of evidence-based anthelmintic treatment protocols for equine helminth control in the UK

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Abstract

Interval treatment control programmes used widely in equine helminth control have favoured the development of anthelmintic resistance worldwide. Best practice guidelines have been designed to address resistance and include the requirement for improved pasture hygiene to break helminth transmission cycles, along with anthelmintic application informed by the results of diagnostic tests to reduce selection pressure for resistance. Using an online questionnaire, this study examined uptake of measures recommended in these guidelines by UK horse owners. The survey comprised 58 questions spanning grazing management, anthelmintic use and use of faecal egg count (FEC) testing to inform treatment decisions. Analysis was carried out using a combination of Chi-square and Mann-Whitney tests. In total, 705 owners responded and, following specific exclusion criteria, the responses of 652 individuals were analysed. The majority of the respondents owned <20 horses on private premises or livery yards in England. The main outputs of the survey were as follows. Overall, 60.9% of respondents used FEC tests to inform the requirement to administer anthelmintics, with macrocyclic lactones the most frequently-used anthelmintics. Of the respondents, 38% obtained advice on anthelmintic choice from their veterinarians; however, many respondents (43.8%) purchased anthelmintics via the internet. Encouragingly, 74.4% of respondents stated that they practiced good pasture hygiene

by removing dung from pasture. Generally, there were differences between the responses of participants who based anthelmintic treatments on FEC testing (targeted treatments; TT) and those who practiced calendar-based anthelmintic treatments (interval treatments; IT). Briefly, the "key" findings from the Chi-square analysis included higher levels of satisfaction with the level of knowledge about equine parasites/parasitic diseases and higher levels of concern about anthelmintic resistance from TT-respondents compared to IT-participants. Confusion on the interpretation of quarantine recommendations was identified in this study group and there was poor uptake of testing for anthelmintic effectiveness. Overall, compared to previous reports, this study indicated improved engagement of UK horse owners with some helminth control practices recommended to reduce the spread of anthelmintic resistance. However, a proportion of respondents did not utilise these practices and there were still important gaps in the use of appropriate quarantine and efficacy testing. These identified gaps must be taken into consideration in knowledge dissemination activities in the future.

Keywords: helminths; equine; questionnaire; anthelmintics; anthelmintic resistance; faecal egg count tests.

1. Introduction

Broad spectrum anthelmintics have been used for over 50 years for controlling equine helminth infections. A popular approach has been to administer anthelmintics to all animals within a group using interval treatment protocols, introduced in the 1960s following studies which sought to control the pathogenic nematode, *Strongylus vulgaris* (Drudge and Lyons, 1966). Over the years, the widespread use of interval treatment protocols has led to substantial reductions in *S. vulgaris*-associated disease; however, it has promoted development of anthelmintic resistance, particularly in the highly prevalent cyathostomin group of nematodes [reviewed by (Kaplan, 2002; Kaplan and Nielsen, 2010; von Samson-Himmelstjerna, 2012; Matthews, 2014; Peregrine et al., 2014; Tzelos and Matthews, 2016)]. Resistance to benzimidazoles and tetrahydropyrimidines, as measured by faecal egg count reduction test (FECRT), is widespread in cyathostomin populations worldwide (Matthews, 2014; Peregrine et al., 2014). Apart from one study in Brazil (Canever et al., 2013) and one in UK donkeys (McArthur et al., 2015), published reports of macrocyclic lactone effectiveness assessed by FECRT have indicated acceptable efficacy against cyathostomins at two weeks after treatment (Traversa et al., 2009; Relf et al., 2014). However, shortened strongyle egg reappearance periods (ERP) after ivermectin and moxidectin treatments has been reported in

95 several countries (von Samson-Himmelstjerna et al., 2007;
96 Rossano et al., 2010; Lyons et al., 2011; Geurden et al., 2014;
97 Relf et al., 2014; van Doorn et al., 2014; Tzelos et al., 2017). A
98 shortened ERP is considered as an early indicator of resistance
99 (Sangster, 2001). Although ivermectin and moxidectin appear
100 effective in terms of reducing egg shedding two weeks after
101 treatment, these compounds may be less effective against larval
102 and early-adult stages, which mature and produce eggs before
103 the standard ERP (Lyons et al., 2009; Lyons et al., 2010; Lyons
104 and Tolliver, 2013). Ivermectin resistance is also reported as
105 widespread in *Parascaris equorum* (Reinemeyer, 2009).

106 Anthelmintic resistance is a major welfare threat,
107 particularly to young animals which are more susceptible to life-
108 threatening burdens of these parasites (Reid et al., 1995). It is
109 therefore essential that anthelmintic potency is protected and that
110 treatment applications be informed by diagnostic tests (Herd,
111 1993; Proudman and Matthews, 2000; Lester and Matthews,
112 2014; Nielsen et al., 2014a) and integrated with improved
113 pasture hygiene practices such as dung removal to reduce
114 infection levels in the environment (Herd, 1986; Corbett et al.,
115 2014; Tzelos et al., 2017). Despite this approach being advocated
116 for >20 years, surveys across different countries have indicated
117 relatively low horse-owner uptake of the principals behind
118 sustainable methods of helminth control (O'Meara and Mulcahy,
119 2002; Lind et al., 2007; Fritzen et al., 2010; Relf et al., 2012;

120 Nielsen et al., 2014b; Stratford et al., 2014; Bolwell et al., 2015;
121 Robert et al., 2015; Salle and Cabaret, 2015; Rosanowski et al.,
122 2016). In particular, the common finding in the aforementioned
123 studies from 2002 to 2015 was the respondents' high levels of
124 concern about anthelmintic resistance and the relatively low
125 percentage of FEC testing before anthelmintic treatment (range
126 among studies 0-50.6%).

127 There are nil survey-related studies in equine-
128 parasitology in the UK published since 2014. The objective,
129 here, was to assess if there was continued improvement in the
130 uptake of evidence-based helminth control practices by horse
131 owners, since there have been several industry-led initiatives
132 promoting diagnostic-led treatment protocols to horse owners
133 over the last decade; for example the Smart Worming
134 Programme (http://www.smartworming.co.uk) and updated
135 guidelines by the British Horse Society
136 (www.bhs.org.uk/~/media/bhs/files/pdf-documents/worm-
137 control.ashx). Furthermore, it is imperative to assess which
138 practices still lack any uptake; for example, field assessment of
139 anthelmintic efficacy, identified previously as not being
140 implemented (Easton et al., 2016).

141

142 **2. Materials and methods**

143 2.1. Questionnaire format

144 A questionnaire was designed using previously
145 published formats to assess equine helminth control measures
146 (Relf et al., 2012; Stratford et al., 2014; Easton et al., 2016), in
147 this case, utilizing the web-based software tool, (SurveyMonkey,
148 https://www.surveymonkey.com/). The questionnaire comprised
149 58 questions divided into a 'Welcome' page with details about
150 the project and requesting consent (n=1); 'General Information'
151 (n=5) exploring demographic details of each respondent;
152 'Worms and Deworming' (n=29) assessing helminth control
153 methods used and attitudes to parasites, treatment, advice and
154 anthelmintic purchasing; 'Faecal Egg Counts' (n=6), which
155 focused on respondent experience regarding FEC tests and
156 anthelmintic efficacy testing; 'Worm Control in Foals' (n=2) and
157 'General Management' (n=12) which investigated additional
158 approaches to helminth control such as the removal of faeces
159 from pasture, stocking density levels and approaches to
160 quarantine. A 'Future Studies' section (n=3) asked whether
161 respondents would be willing to participate in future
162 parasitological studies to assess helminth prevalence and
163 anthelmintic efficacy. The 'Question Logic' function in
164 SurveyMonkey was employed in some questions flows and
165 respondents were directed in specific routes depending on their
166 preceding answer. Most questions were of the closed multiple
167 choice type. There were also open-ended questions and, in some
168 cases, an opportunity for respondents to include additional

comments. The questionnaire is included in Supplementary file 1. The survey was piloted using a small group of horse owners prior to distribution. These pilot survey results were not included in the analyses described below. Ethical approval was granted by the Senior Management Group of Moredun Research Institute when the project was approved for submission. All data were stored on a secure server at Moredun Research Institute, and backed up daily at an external site, with access limited to research project staff. Informed consent was obtained by respondents, and responses were anonymised prior to analysis.

2.2. Questionnaire distribution

The target population was UK individuals who manage and/or own equids. Responses were sought from stud farm and livery yard managers, riding school managers and owners who used livery yards or private premises. The questionnaire was available online for 13 weeks (13 April - 6 July 2015), and was primarily promoted via social media (mainly through posts on Facebook, https://www.facebook.com/). The questionnaire hyperlink was posted to equid-oriented groups on Facebook (n=10) with a short description of the project. A reminder was posted every 2 weeks. In addition, 384 equine practice email addresses were obtained from the British Equine Veterinary Association website (www.beva.org.uk). An email, detailing

study background and an online link to the questionnaire was distributed to practices inviting them to promote the survey to clients via websites, social media and/or newsletters. A direct email was also sent to 518 equine premises, including riding schools and livery yards listed on the British Horse Society website (http://www.bhs.org.uk/professionals/become-bhs-approved/approved-livery-yards). The Horse Trust also promoted the survey on their website (http://www.horsetrust.org.uk/) and Facebook page.

2.3. Data analysis

In terms of selecting respondents to be included in the analysis, data were included when a respondent provided consent to participate (Question 1), had completed the 'General Information' section and provided a response to at least one question in 'Worms and Deworming' section. Respondent answers were then exported to Microsoft Excel (Microsoft Excel for Windows, 2010) and basic descriptive analysis performed in Microsoft Excel. Statistical analyses were carried out using Minitab 17 (Minitab® 17.1.0). Chi-square tests were performed for each question to determine whether the frequency of owners expressing agreement or disagreement with specific statements differed between those respondents that practiced 'interval treatment' (IT; i.e. calendar-based anthelmintic treatments of all

217 animals in a group not informed by diagnostic [i.e. FEC] testing)
218 *versus* 'targeted treatment' (TT; i.e. anthelmintic treatment of
219 animals based on the results of diagnostic [i.e. FEC] tests)
220 protocols. In particular, chi square tests examined whether
221 respondents who followed targeted treatment (TT) protocols
222 (n=397) answered specific questions differently to those that
223 followed interval treatment (IT) protocols (n=161). Those
224 respondents who stated that they followed a different type of
225 protocol to the two stated above (94/652) were not included in
226 this analysis. Due to testing of multiple comparisons (n=53),
227 following correction via Šidák's formula (Sidak, 1967), values
228 of $P \leq 0.0015$ were considered significant. For responses on a
229 ranked (Likert) scale, significant chi-square results on a
230 compressed scale (agree/disagree) were followed by Mann-
231 Whitney tests across the full Likert scale.

232

233 **3. Results**

234 3.1. Demographic features of the study respondents

235 A total of 705 respondents clicked on the hyperlink, 652
236 of which were then included in the analysis. Of the latter, 519
237 respondents completed the survey, and 133 incomplete
238 questionnaires fulfilled the inclusion requirements. Respondent
239 distribution across the UK and general information on the
240 respondents are presented in Table 1. Briefly, respondents were

241 distributed as follows: England (73.5%; 479/652), Scotland
242 (17.9%; 117/652), Wales (7.7%; 50/652) and N. Ireland (0.9%;
243 6/652). The largest proportion of respondents had accessed the
244 survey after learning about it on social media (75.9%; 495/652),
245 followed by direct email (13.5%; 88/652), 'friend/colleague'
246 (8.3%; 54/652) and the Horse Trust website (2.3%; 15/652). A
247 total of 92% respondents (600/652) stated that they were horse
248 owners, 13.8% (90/652) were yard managers and 3.4% (22/652)
249 were stud farm owners/managers (please note that respondents
250 could chose more than one option here). A total of 8.7% (57/652)
251 of respondents owned / managed ≥20 horses, 90.4% (589/652)
252 managed/owned <20 horses and 0.9% (6/652) did not provide
253 horse numbers. A total of 639 respondents stated they
254 owned/managed at least one adult horse (>3 years-old), 120
255 respondents owned/managed at least one "youngster" (1-3 years-
256 old) and 43 respondents stated they owned/managed at least one
257 foal (<1 year-old). The majority of horses were kept on private
258 premises (50.6%; 330/652), followed by livery yards (37.3%;
259 243/652), riding schools (3.4%; 18/652); livestock farms (2.9%;
260 19/652), multi-purpose stables (2.7%; 18/652), stud farms (2%;
261 13/652) and colleges/rescue centres (1.1%; 7/652).

262

263 3.2. Descriptive analysis of responses

An outline of the descriptive results is presented here and summary details for all survey questions are presented in Supplementary file 2. A FEC-directed TT regimens were followed by 60.9% respondents (397/652), whilst 24.7% (161/652) respondents stated that they used calendar-based IT regimens. A further 14.4% (94/652) respondents stated that they followed a "different type" of helminth control protocol, including "strategic" treatments (1-4 times/year) or "irregular" treatments (when they suspected worm infection). One respondent stated that they did not treat their horses with anthelmintics. Of the 395 respondents who stated that they followed a TT helminth control protocol, 54.9% (217/395) had moved from an IT protocol or "strategic deworming" programme in the previous 1-5 years, 24.6% (97/395) respondents had changed their type of helminth control to a TT one in the previous 5-10 years, 13.7% (54/395) in the previous year, 1.5% (3/395) stated that they did not know when they had made this change and 5.3% (21/395) stated they had always followed a TT programme. When asked who influenced them in changing their helminth control practice to a TT approach, 30.4% (120/395) of the respondents indicated that it was their veterinarian who had done so and 32.4% (128/395) stated that they were influenced by 'Other' factors, with the majority (26.3%; 104/395) stating that it was personal research via the internet, academic literature or magazines.

With regard to respondent opinions on their own level of knowledge of parasites/parasitic diseases, 37.5% (191/509) were 'neither satisfied nor dissatisfied', 27.1% (138/509) and 11.8% (60/509) were 'satisfied' and 'very satisfied' with their knowledge levels, respectively. The remaining 16.3% (83/509) and 7.3% (37/509) were 'dissatisfied' and 'very dissatisfied' with their knowledge of parasites and parasitic diseases, respectively. There was a high level of respondent recognition of worm species names listed in the survey. In order of importance, the helminths considered as key targets to treat were: small strongyles (38.7%; 197/509), *Anoplocephala perfoliata* (25.3%; 129/509), large strongyles (21%; 107/509), *Parascaris equorum* (5.1%; 26/509), *Fasciola hepatica* (1.6%; 8/509), *Oxyuris equi* (1.4%; 7/509) and *Gasterophilus intestinalis* (1%; 5/509). Regarding anthelmintic resistance, 32.2% (161/500) and 37.2% (186/500) of respondents were 'concerned' and 'very concerned' about this issue, respectively. Despite these levels of concern of anthelmintic resistance, 75.2% (376/500) respondents stated they were not aware of the anthelmintic sensitivity status of the worm populations on the premises where their horse(s) grazed.

Macrocyclic lactones were the most frequently used anthelmintics [ivermectin (42.5%; 197/463), moxidectin/praziquantel (35.6%; 165/463), ivermectin/praziquantel (35%; 162/463) and moxidectin (32%; 148/463)]. Use of other classes of anthelmintics was as follows:

fenbendazole as a single dose 5.2% (24/463) or a 5-day course 15.8% (73/463), pyrantel 17.7% (82/463) and praziquantel 22.5% (104/463) of respondents. A small proportion of respondents stated that they used “herbal products” (4.8%; 22/463). A total of 16% (74/463) of respondents were not familiar with the chemical names of anthelmintics specified in the survey. The majority of respondents stated that they “specifically targeted” tapeworm infections (77.3%; 358/463), with almost all respondents stating that they had used a product that contained praziquantel for tapeworm control. Over 60% (61.8%; 286/463) of respondents stated that they “specifically targeted” encysted stage cyathostomin infections with anthelmintic treatment. For small strongyles, 70.3% (201/286) respondents stated they targeted encysted larvae with a product containing moxidectin, 5.6% (16/286) five-day fenbendazole, 1.7% (5/286) ivermectin and 22.4% (64/286) stated that they did not know or followed their prescriber’s advice for this type of treatment.

When selecting an anthelmintic, 38% (176/463) of respondents stated that they sought advice from a veterinarian, 19.2% (89/463) from a suitably qualified person (SQP), 16.8% (78/463) from a FEC service company, 4.8% (22/463) from an internet retailer, 1.5% (7/463) from a pharmacist, whilst 8.2% (38/463) of the respondents did not seek advice before purchasing an anthelmintic. When considering where thy

purchased anthelmintics from, 20.7% (96/463) of respondents stated that they bought anthelmintics from same source from which they sought advice on anthelmintic selection. The highest proportion (43.8%; 203/463) of respondents stated they used an internet retailer for the purchase of anthelmintics. The remainder stated that they used a veterinarian (3.2%; 15/463), SQP (14.7%; 68/463) or pharmacist (3%; 14/463) for their anthelmintics purchase.

In the section pertaining to 'Worm control in foals', 76.2% (337/442) of respondents stated that they did not have foals at their premises. From the remaining 105 participants that answered this question, 66.7% (70/105) of respondents stated that they anthelmintic treated the foals at their premises. The remaining participants stated that they did not treat foals (21.9%; 23/105) or they did not know (11.4%; 12/105). On the question, "How does the deworming of foals compare to that of adult equines at your premises?", the respondents who anthelmintic treated foals stated: 'Same anthelmintic(s) are used, but different dosing regimen' (37.1%; 26/70); 'Different anthelmintic(s) are used' (22.9%; 16/70); 'Same protocol as in adults' (17.1%; 12/70); 'Other' (14.3%; 10/70); and, 'I do not know' (8.6%; 6/70).

With regards to general management (Supplementary file 2), 74.4% (392/527) of respondents stated that they practiced dung removal from pasture, 25% (132/527) did not remove dung

and 0.6% (3/527) did not know whether this was applied at their premises. Additionally, 53.6% (210/392) of respondents that practiced dung removal from pasture stated that dung was removed daily and 31.4% (123/392) stated that it was removed every 2-7 days. The remainder stated that the frequency of dung removal was as follows: every 8-14 days (6.6%; 26/392), 15-28 days (4.1%; 16/392), less often (3.8%; 15/392) or do not know (0.5%; 2/392).

When asked whether new arrivals to the premises were treated with anthelmintics, 25.6% (137/535) of respondents stated that their premise was a closed yard, 9.5% (51/535) of respondents did not anthelmintic treat new arrivals and 6.5% (35/535) did not know what new arrivals were treated with. A total of 58.3% (312/535) of respondents stated they administered anthelmintic(s) to new arrivals with the preference for "quarantine treatment" as follows; moxidectin/praziquantel (25.9%; 81/312), ivermectin/praziquantel (20.1%; 63/312), a 5-day course fenbendazole (10.5%; 33/312), ivermectin (8.9%; 28/312), moxidectin (6.4%; 20/312), praziquantel (2.6%; 8/312), pyrantel (1.9%; 6/312), a single-dose of fenbendazole (1.9%; 6/312) and a "herbal product" (0.3%; 1/312). A total of 18.8% (59/312) of respondents did not know the anthelmintic used, 7% (22/312) did not recognize the chemical terms and 19.5% (61/312) selected "other", the majority stating that treatment

388 depended on ‘FEC testing’, ‘advice from a prescriber’, ‘time of
389 year’ and ‘last anthelmintic used’.

390

391 3.3. Chi-square and Mann-Whitney analyses of survey answers
392 by respondents who reported using targeted treatment (TT)
393 *versus* interval treatment (IT) protocols

394 In order to determine whether the frequency of owners
395 expressing agreement or disagreement on specific aspects/views
396 of helminth control differed between the groups categorized as
397 respondents who followed a TT protocol and respondents who
398 followed an IT protocol, Chi-square and Mann-Whitney tests
399 were performed (see Supplementary files 3 and 4 for Chi-square
400 and Mann-Whitney test results, respectively). In particular, for
401 responses on a ranked or Likert scale, significant chi-square
402 results were followed up with a Mann-Whitney test, and only
403 those results that produced significant values using both tests are
404 reported here. The P-values presented below are from the Chi-
405 square tests, whilst the P-values from the Mann-Whitney tests
406 can be found in Supplementary file 4.

407 Respondents who followed TT protocols were more
408 likely to state that they were more ‘satisfied’ with their level of
409 knowledge about equine parasites/parasitic diseases than those
410 that used IT protocols (TT: 29.62%, 109/368; IT: 20%, 28/140;
411 P=0.0002). Likewise, the TT group respondents were more

likely to state that they were ‘very concerned’ about anthelmintic resistance than those who implemented an IT protocol (TT: 41.32%, 150/363; IT: 26.28%, 36/137; P=0.0006).

The TT group of respondents were more likely to ‘strongly agree’ with the following statements: “I believe that wormers are bad for my horse and want to minimise their use as far as possible” (TT: 21.32%, 71/333; IT: 5.6%, 7/125; P<0.0001); “I am aware of the emergence of wormer resistance in horses and this concerns me” (TT: 59.46%, 198/333; IT: 34.4%, 43/125; P<0.0001); and, “Knowing how many eggs are being shed by horses helps me to manage grazing so that horses do not encounter heavily contaminated pastures” (TT: 25.31%, 81/320; IT: 7.38%, 9/122; P<0.0001). Those respondents who followed TT protocols were significantly more likely to ‘strongly disagree’ with the statements “FEC are too expensive and provide no advantage over administering wormer regardless of results” (TT: 52.5%, 168/320; IT: 4.1%, 5/122; P<0.0001) and “Not enough advice on what to do arrives with FWEC for them to be useful to me” (TT: 36.56%, 117/320; IT: 6.56%, 8/122; P<0.0001).

Those respondents who followed an IT protocol were more likely to ‘strongly agree’ with the statement “If FEC were quicker and cheaper I would use them more” (TT: 9.69%, 31/320; IT: 25.41%, 31/122; P<0.0001). On the other hand, the IT group were more likely to ‘disagree’ with the statement

437 “Worms are something our horses have to live with and are not
438 always bad for them” (TT: 29.43%, 98/333; IT: 48%, 60/125;
439 P<0.0001).

440 In terms of reported anthelmintic treatment practices, the
441 respondents in the TT group were more likely to select ‘yes’
442 when asked if they treated for tapeworm (TT: 81.9%, 276/337;
443 IT: 65%, 82/126; P<0.0001) or encysted cyathostomin larvae
444 (TT: 66.77%, 225/337; IT: 48.41%, 61/126; P<0.0001). Finally,
445 the IT group of respondents were more likely to seek advice from
446 an internet retailer compared to TT participants (TT: 2.97%,
447 10/337; IT: 9.52%, 12/126; P<0.0001).

448

449 **4. Discussion**

450 This study examined helminth control approaches of
451 horse owners in the UK. Participation was similar to a recent
452 survey in the UK (Easton et al., 2016) and relatively higher than
453 previous UK studies that focused on particular regions or sectors,
454 i.e. 193 responses in a study focused on horse establishments in
455 Scotland and 61 responses in a study focused on UK
456 thoroughbred establishments (Relf et al., 2012; Stratford et al.,
457 2014). An important finding was that 60.9% of respondents
458 stated that they followed a TT regimen based on FEC testing, the
459 majority of whom switched from IT protocols in the preceding
460 1-5 years before this survey. The percentage of owners following

461 a TT strategy based on FEC test results reported here is the
462 highest reported to date. For example, a study conducted in
463 Scotland in 2010 (Stratford et al., 2014), indicated that 40% of
464 respondents followed TT regimens. The last UK-wide survey,
465 conducted in 2009-2010, targeted Thoroughbred breeding farms
466 and in that case, 100% of respondents followed an IT regimen
467 (Relf et al., 2012). Studies based outside of the UK also
468 demonstrated a lower uptake of TT protocols; for example, 25%
469 in France (Salle and Cabaret, 2015); 20% in New Zealand
470 (Bolwell et al., 2015); 30% in the USA (Robert et al., 2015);
471 50.6% in Denmark (Nielsen et al., 2014b); 0% in Germany
472 (Fritzen et al., 2010); 1% in Sweden (Lind et al., 2007) and 16%
473 in the Republic of Ireland (O'Meara and Mulcahy, 2002).

474 The results presented here should be interpreted in
475 consideration of inevitable bias. The sample size, although
476 higher than similar UK studies (Relf et al., 2012; Stratford et al.,
477 2014), is approximately 0.15% of the estimated 446,000 horse-
478 owning premises quoted in The National Equestrian Survey
479 2015 (BETA, 2015). The distribution/promotion of the current
480 survey was online, which might lead to non-response bias by
481 only reaching those individuals with access to the internet.
482 Nevertheless, a recent study has demonstrated that online
483 questionnaires could potentially replace hard-copy
484 questionnaires without compromising response rates (Hohwu et
485 al., 2013). This questionnaire was partly distributed via equine

veterinarian practices to their clients, which could also have skewed the results towards approaches that those practices promote. It is also possible that horse owners who participated here were more in favour of using FEC tests and the currently-recommended approaches. Finally, there could also be a social desirability bias. This type of response bias is the increased likelihood that survey participants select answers in such a manner that will be viewed favourably by others. This type of bias was recently described in a horse owner survey as a factor influencing the use of FEC tests before treatment (Rose Vineer et al., 2017).

Here, respondents had a good general knowledge of parasites/parasitic disease. When asked to identify the most important parasites to target, many responses matched the reports in scientific articles; namely cyathostomins as the most important parasite to target, followed by tapeworm and large strongyles (Kaplan and Nielsen, 2010). Respondents using TT protocols were more satisfied with their level of parasitology knowledge compared to IT-participants. This is similar to a previous UK survey study that also showed that horse owners who were less satisfied with their level of knowledge were 57% less likely to follow TT strategies (Allison et al., 2011). Nevertheless, in the current study, just under a quarter of respondents were still not satisfied with their knowledge levels,

highlighting a requirement for improving knowledge transfer to horse owners in the UK.

The most commonly used anthelmintic class reported in previous studies in the UK and elsewhere was the macrocyclic lactones (Fritzen et al., 2010; Hinney et al., 2011; Relf et al., 2012; Stratford et al., 2014; Robert et al., 2015; Salle and Cabaret, 2015) and this was the case for the current study. Note that treatment frequency was not recorded here because it was difficult to assimilate information in the TT group as, at certain times, treatment was linked to egg shedding levels in individuals. The high reliance on macrocyclic lactones needs to be addressed, especially in IT programmes, because of the strong selection pressure for resistance caused by regular treatments using the same type of compound (Matthews, 2008; Tzelos and Matthews, 2016). A total of 74 (out of 463) respondents stated that; "I do not know what these chemical terms are". This is of concern and indicates sub-standard information transfer at the point of sale or in the advice given before purchase.

Anthelmintic resistance was the topic that most respondents were concerned about, with those using TT protocols significantly more concerned about this issue compared to the IT group as indicated by the Chi-square analysis here. Nevertheless, approximately 75% of the overall study population were not aware of the status of anthelmintic resistance in worm populations at their premises. This particular

discrepancy has also been reported in the past in a questionnaire study examining the interaction of horse owners with anthelmintic prescribers (Easton et al., 2016). Potential reasons associated with the lack of efficacy testing include the perception of additional labour in collecting the samples and the additional economic cost. Another potential reason might be the lack of promotion or emphasis of efficacy testing by prescribers to horse owners. Current recommendations are that a FECRT be performed each year to avoid using ineffective anthelmintics (Tzelos and Matthews, 2016). Going forward, considering the levels of anthelmintic resistance reported in cyathostomins and in *P. equorum* (Raza et al., 2019), improved knowledge transfer from prescribers to horse owners needs to highlight the benefit of efficacy testing.

Although the majority of respondents sought advice on anthelmintic selection from a veterinarian or SQP, only a small proportion bought anthelmintics from these sources, with the main route of purchase being internet retailers. A recent analysis of UK horse owner anthelmintic purchasing behaviours similarly demonstrated that most respondents received advice from veterinarians before purchasing dewormers online (Easton et al., 2016). In the current study, it was more likely that respondents would follow an IT protocol when advice was sought from an internet retailer. Getting information from an internet retailer is not ideal; one study showed that horse owners who purchased

anthelmintics online most often stated they received little/no specific advice at the point of purchase (Easton et al., 2016). Face-to-face interactions with veterinarians or other qualified prescribers (in the UK, SQPs or veterinary pharmacists) should be encouraged as it has been shown that horse owners who purchased anthelmintics from veterinarians (and other prescribers, SQPs or veterinary pharmacists) were more likely to be recommended FEC test analysis in their interaction than online retailers (Easton et al., 2016).

It was more likely for IT-participants to treat *all* new acquisitions with anthelmintics than those following a TT protocol. Approximately 12% of TT-participants performed FEC analysis on new arrivals and applied a treatment based on the test results. The latter approach would not inform on the presence of immature helminth stages and standard FEC analysis is unlikely to provide information on the presence of *Anoplocephala perfoliata* infection. Thus, it is recommended that new acquisitions be treated with a product containing moxidectin to target strongyle larvae and adult stages and that these horses be kept off pasture for at least 3 days after treatment (Tzelos and Matthews, 2016). Testing for *A. perfoliata* infection using an ELISA-based test (in the UK) or treatment with praziquantel is also recommended (Tzelos and Matthews, 2016). Here, a product containing moxidectin was used by only 32.3% of respondents when treating new arrivals. Best practice

585 quarantine recommendations need to be disseminated more
586 widely.

587 Foal treatment was another aspect that a knowledge gap
588 was identified. Current suggestions for foal treatment include
589 specific treatments at specific time due to the relatively long
590 prepatent period of ascarid infections, which should be the main
591 focus for foals (Tzelos and Matthews, 2016). Most participants
592 that replied to this question (37.1%; 26/70) stated that they used
593 the same anthelmintics with adult horses, but with different
594 dosing regimen. It is worth mentioning here that a total of 39/70
595 respondents that replied to the previous question stated that they
596 had nil foals. This discrepancy could be because they might not
597 had foals at their premises at the time the survey took place, but
598 they did in the past and felt like they should answer the question.
599 Generally, more emphasis should be given in advice on helminth
600 control practices in foals in the future.

601 Dung removal from pasture plays a crucial role in
602 reducing infection pressure in the environment (Herd, 1986).
603 Here, 74.4% respondents stated that they removed dung, similar
604 to levels in a recent UK survey where ~80% of respondents
605 stated that they did this (Easton et al., 2016). These levels of
606 uptake are the highest reported to date and are higher than
607 reported in other countries (O'Meara and Mulcahy, 2002; Lind
608 et al., 2007; Fritzen et al., 2010; Bolwell et al., 2015) and offer
609 hope that some messages on sustainable helminth control are

610 reaching the target audience in the UK. Potential reasons
611 associated with the unwillingness of horse owners/managers to
612 engage with this activity include land gradient, increased horse
613 numbers, labour associated, limited staff resources and/or lack
614 of knowledge.

615

616 **5. Conclusion**

617 Overall and despite the aforementioned limitations, the
618 results of this study highlight; 1) a recent shift from IT to TT
619 strategies on many yards in the UK, 2) some confusion in the
620 interpretation of current quarantine treatment guidelines, 3) a
621 lack of anthelmintic efficacy testing overall and 4) high
622 proportions of the horse owners purchasing anthelmintics online.
623 The areas in which knowledge gaps were identified should be
624 considered to enhance knowledge dissemination in the future.
625 Improving knowledge in horse owners, especially in those who
626 do not use a face-to-face interaction for advice on helminth
627 control, could be facilitated by developing accurate knowledge-
628 transfer tools such as free guidelines or decision support tools.
629 Alternatively, these issues could be addressed by altering
630 prescribing legislation to promote better quality face-to-face
631 interactions when anthelmintics are sold and minimise the
632 amount of anthelmintics purchased online.

633

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639

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